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RESEARCH NOTE

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LARGER MELTWATER FLOWS COME LATER

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Introduction

Description of the "timing" of streamflow from snowmelt is needed to determine the effects of vegetation management aimed at increasing the snowpack and delaying its melting. Research on possible methods of forest management to attain these aims has been conducted since 1956 by the Pacific Southwest Forest and Range Experiment Station with the California Department of Water Resources. This paper is a progress report on studies of methods of describing the time distribution of streamflow through the year.

One somewhat surprising by-product of the study is the finding that, on high-elevation snowmelt streams at least, "the greater the flow, the later it comes." This interdependence of two streamflow characteristics will have to be considered in any evaluation of the separate effect of treatment on quantity and timing of streamflow.

Streamflow timing has been characterized heretofore almost entirely by one of two criteria:

1. the date of "momentary maximum" or sometimes of greatest daily flow;

2. the percentage of total annual flow occurring during one or more fixed months.

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[1] Dr. Court was Meteorologist (Hydrology) in the Snow Management Research program, Pacific Southwest Forest and Range Expt. Sta., Berkeley, July, 1956 to July, 1960.

Momentary maximum dates and amounts are published for each stream each year in the U.S. Geological Survey's Water Supply Papers, and are listed by years in a recent compilation through September, 1950. Dates of greatest daily flow are obtainable from the annual tabulations of streamflow, but are not summarized in the compilation although the flow of the "Minimum Day," but not its date, is listed for each year.

Characterization of an entire distribution by the date of its "momentary" or daily maximum discards much valuable information. And such a date may be misleading: a short March peak may be greater than the peak during sustained flood flows in May. In describing streamflow timing, some use should be made of all the records.

The percent of annual flow occurring during the arbitrary 4-month "melt season", from April 1 through July 30, has been used to characterize California streams. Of 13 major streams of the Sierra Nevada (table 1):

...northern streams have about half their flow during these 4 months

...the middle Sierra streams about two-thirds

...and the southern Sierra streams between half and three-quarters.

...The San Joaquin and Kings Rivers show the most pronounced concentration of streamflow in the April-July period.

Records of four of the high-elevation tributaries of these rivers were studied in developing more refined methods of describing streamflow "timing."

Half-flow Dates

Statistical theory indicates that the most precise average of a cyclic or recurrent phenomenon, such as the annual distribution of streamflow, is obtained by considering the year as a circle and adding vectorially the daily (or weekly or monthly) values. Such a procedure would be useful for some purposes but involves so much computation that a special computer program should be written. While theoretically desirable, it may have no special advantage over simpler averages.

As a possible indicator of streamflow timing, the dates of median and quartile flow were investigated. The date of median flow is the date on which half of the flow of the year (or some other period, if specified) has passed. For example, the total flow of the North Kings River at Cliff Camp from Oct. 1, 1954 to Sept. 30, 1955 was 203.2 thousand acre-feet (TAF). The date of median flow is the date on which the accumulated flow since Oct. 1, is half of this, or 101.6 TAF. From the annual Water Supply Papers, the median date was found to be May 23.

Table 1.--Annual (Oct.-Sept.) and melt season (April-July) flows of major Sierra Nevada streams[1] and melt season flow as percentage of annual flow

Stream	Annual	Melt season	Percent of annual
	- 1,000 acre-feet -		
Sacramento River near Red Bluff	8,049	2,554	32
Feather River near Oroville	4,416	2,045	46
Yuba River at Smartville	2,320	1,162	50
American River at Fair Oaks	2,713	1,440	53
Mokelumne River at Clements[2]	747	505	67
Stanislaus River near Knights Ferry[3]	1,160	777	67
Tuolumne River at La Grange	1,854	1,263	68
Merced River at Exchequer	979	654	67
San Joaquin River at Friant	1,762	1,277	72
Kings River at Piedra	1,660	1,241	75
Kaweah River near Three Rivers	407	279	69
Tule River near Porterville	102	49	48
Kern River near Kernville	718	472	66

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[1] All data are normals computed by the California Department of Water Resources for the 50-year period 1905-6 to 1954-55.

[2] At Mokelumne Hill after 1929.

[3] Below Melones after 1923.

Similarly, the dates of first and third quartile flow are the dates on which the accumulated flows were one-fourth and three-fourths of the total. They were May 4 and June 6, 1955, at Cliff Camp.

For convenience, these dates will be called the quarter-flow, half-flow, and three-quarter-flow dates. The number of days between the quarter-flow and three-quarter-flow dates is the half-flow interval. These dates, and intervals, were computed for four high-elevation watersheds with 29 years of streamflow records in the San Joaquin and Kings River Basins. Gage elevations, drainage areas, and mean annual flows of the four basins used were:

	Elevation (Ft. m.s.l.)	Area (Sq. mile)	Flow (TAF)
Pitman Creek below Tamarack Creek	7,005	23	27
Mono Creek below Lake Thomas A. Edison	7,400	92	105
Bear Creek near Lake Thomas A. Edison	7,400	54	62
North Kings River near Cliff Camp	6,140	174	252

Discussion

"Momentary maximum" dates show much more variability than half-flow dates. On Pitman Creek and the North Kings River, three and four momentary maxima, respectively, came during autumn or winter; the earliest was on Oct. 30, 1946, on Pitman Creek. But on Mono and Bear Creeks all came after May 6, as late as mid-July.

Only one half-flow date came before April 1--on Pitman Creek on Jan. 22, 1951, following the heavy rains and floods of December 1950.

Means and standard deviations of momentary maxima and of half-flow dates are given in table 2, together with the mean half-flow intervals and the certain regression data. For Pitman Creek, the mean half-flow date and interval were computed with and without 1950-51, the year of the winter half-flow date resulting from heavy flows in early winter.

To eliminate the effect of erratic winter flows, the half-flow dates and intervals were computed for the half-year beginning April 1, for both Pitman and Bear Creeks; results also are given in table 2.

Omitting the first half of the water year changes the half-flow dates only 4 or 5 days, and reduces the standard deviation of such dates somewhat at Pitman Creek, not at all at Bear Creek. Standard deviations on the whole are small; the half-flow dates have almost a normal distribution, so that in about two-thirds of the years the half-flow date is within one standard deviation of the mean.

Table 2.--Dates and standard deviations of momentary maximum flows and of half-flow passage, lengths of half-flow intervals, and characteristics of column-date regressions, for four high-elevation streams in the southern Sierra Nevada

Stream	Dates of--				Half-flow interval, days	Regression		
	Momentary max.		Half-flow			Slope		Corr. r
	Mean	s.d.	Mean	s.d.		%/day	day/%	
Pitman Creek (all years)	April 21	60	May 11	21	35	--	--	--
Pitman Creek (1 year out)	--	--	May 13	12	31	1.7	0.099	.41
Pitman Creek (Apr-Sept)	--	--	May 16	10	27	3.1	.110	.62
Mono Creek (all years)	June 2	9	June 1	11	49	2.3	.184	.65
Bear Creek (all years)	June 4	18	June 4	12	47	2.0	.218	.66
Bear Creek (Apr-Sept)	--	--	June 8	12	40	2.2	.237	.72
North Kings (all years)	May 2	52	May 15	12	38	2.2	.174	.62

The half-flow interval is surprisingly similar for the different basins, being in the neighborhood of 40 days. This indicates that as much water comes down these streams during a peak 40-day period as flows during the entire rest of the year.

The last two columns of table 2 give the slope of the regression line of annual (or semiannual) flow on the half-flow date, and the corresponding correlation coefficients. Such regression lines are shown in figure 1 (solid line), in which the streamflow of each year is plotted against the corresponding half-flow date. The inverse regression, half-flow date against streamflow is also shown (broken line). For ease of comparison, all flows are expressed as percentages of the means for the periods used.

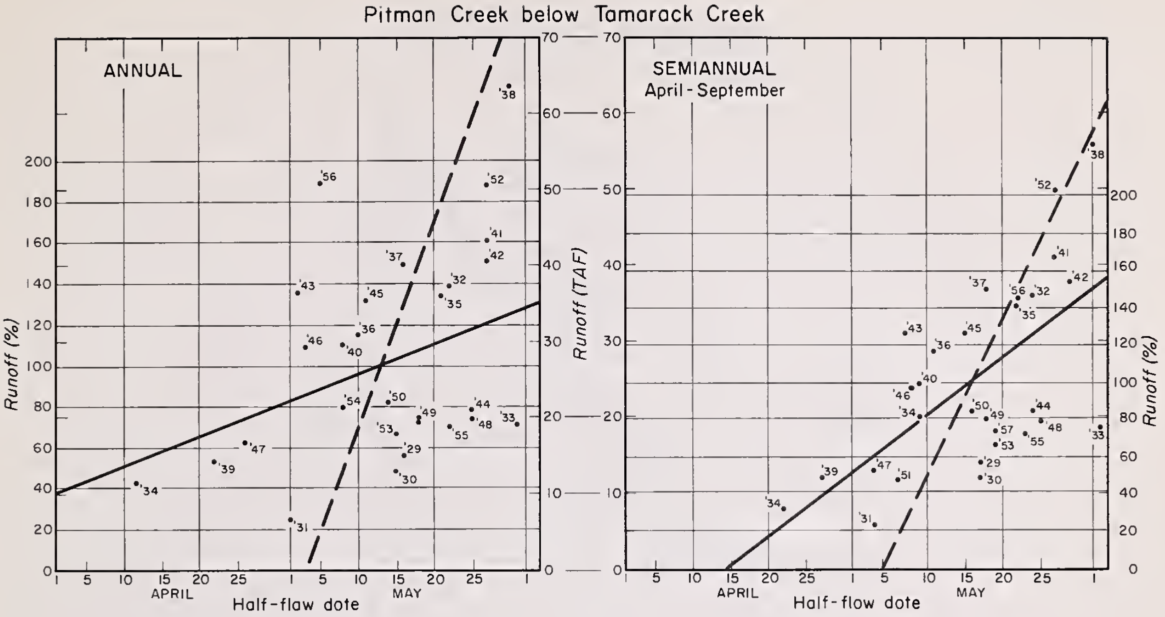
These regression slopes are between 2 and 3 percent per day, indicating that the total annual flow increases by that much for each day's delay in the half-flow date past its average value. (Conversely, for streamflow, 100 percent greater than normal, the half-flow date is delayed 17 days.) The correlations, while not very high, show that the inter-dependence is real, as also is revealed by the graphs themselves.

Conclusion

Half-flow dates, defined as the dates on which half of the year's total streamflow has passed, appear to be useful measures of streamflow "timing." For studying possible changes in streamflow regime caused by watershed management practices, especially vegetational manipulation aimed at increasing snowpack and delaying snowmelt, they seem to be more suitable than the date of momentary maximum flow. They are more sensitive to changes in regime than another criterion in general use, the percentage of flow occurring during one or more fixed months.

Whether the half-flow date is the best or even a good criterion for use in analyses of streamflow timing can be determined only by further investigation. However, the strong dependence of total streamflow on half-flow date will have to be considered in any analysis. Presumably the same dependence will apply also to any other measure of streamflow "timing."

Pitman Creek below Tamarack Creek



Bear Creek near Vermillion Valley

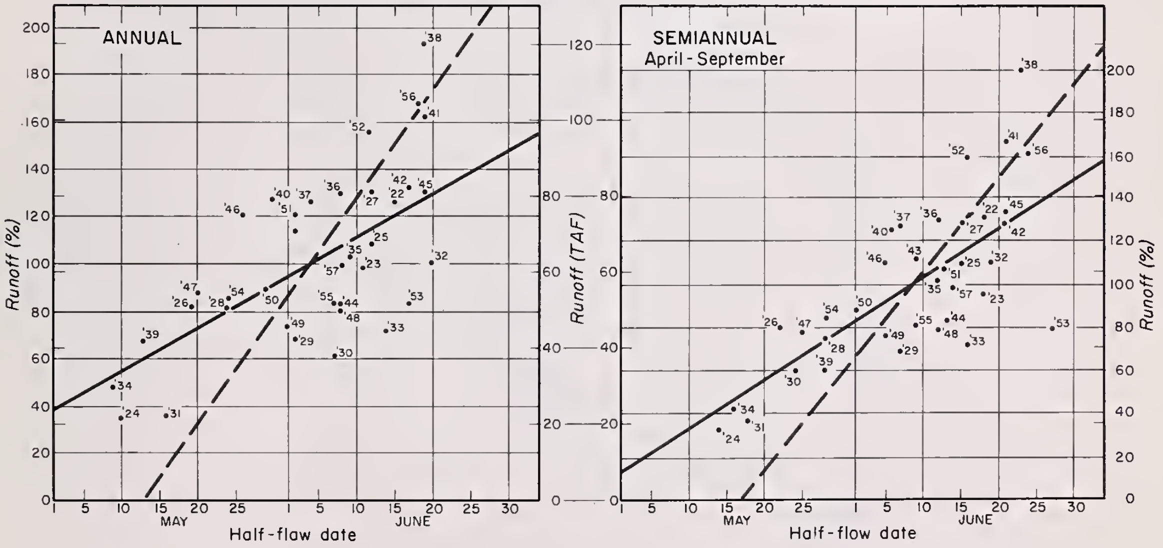
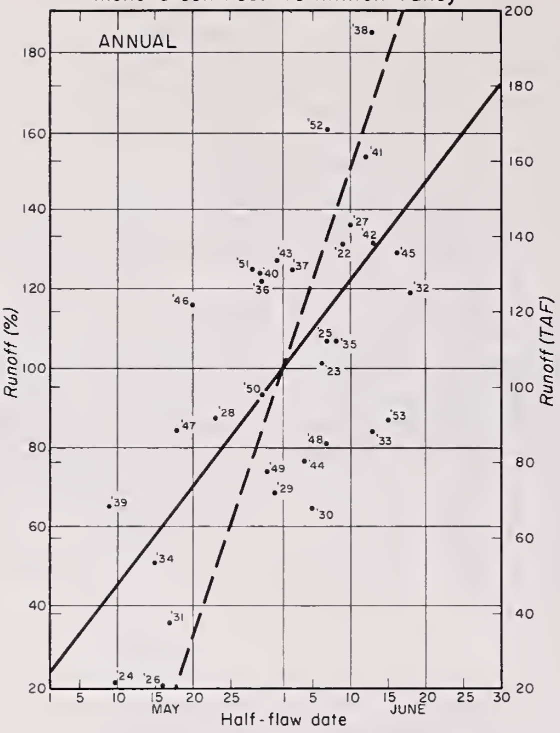


Figure 1.--Annual streamflow of four high-elevation streams in the southern Sierra Nevada and semiannual (April-September) for 2 of these streams, (expressed both in AF and percent of average) plotted against half-flow date, defined as the date on which accumulated streamflow since October 1 is half the total for the year.

Mono Creek near Vermillion Valley



North Kings River near Cliff Camp

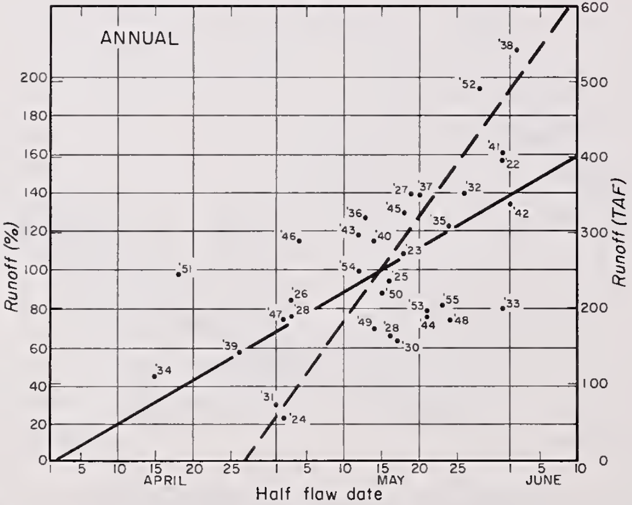


Figure 1 (continued)